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HYDROMECHANICAL PROPERTIES OF AN ISOLATED WING MOVING ABOVE A S--ETC(U)
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FOREIGN TECHNOLOGY DIVISION

HYDROMECHANICAL PROPERTIES OF AN ISOLATED WING MOVING ABOVE A SCREEN

By

S. V. Koval'chuk, I. P. Tkachenko

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Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α	α	*α*		Nu	Ν	ν	
Beta	Β	β			Xi	Ξ	ξ	
Gamma	Γ	γ			Omicron	Ο	ο	
Delta	Δ	δ			Pi	Π	π	
Epsilon	Ε	ε	*ϵ*		Rho	Ρ	ρ	*ϱ*
Zeta	Ζ	ζ			Sigma	Σ	σ	ς
Eta	Η	η			Tau	Τ	τ	
Theta	Θ	θ	ϑ		Upsilon	Τ	υ	
Iota	Ι	ι			Phi	Φ	φ	ϕ
Kappa	Κ	ϰ	κ	*ϰ*	Chi	Χ	χ	
Lambda	Λ	λ			Psi	Ψ	ψ	
Mu	Μ	μ			Omega	Ω	ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

---

rot	curl
lg	log

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HYDROMECHANICAL PROPERTIES OF AN ISOLATED WING MOVING ABOVE A SCREEN

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When a wing moves near the interface of two mediums, its hydromechanical characteristics change relative to those in an unbounded fluid. It is impossible to create devices which use the effect of a solid or liquid wall without considering these changes. Increasing lift, decreasing drag, and displacing the center of pressure along the wing chord are all factors which are considered when constructing airfoil systems and determine the approach to the problem of the stability of the device.

We will start with the general differential integral equation for a hydrofoil [2]. The boundary condition

$$\left.\frac{\partial\varphi}{\partial y}\right|_{y=0}=0. \qquad (1)$$

corresponds to small Froude numbers $(Fr_{*}\to 0)$

We can replace the fluid for a solid wall[1], i.e., return to condition (1), during movement at high speeds above the interface.

[Footnote: [1]See the correct derivation of the boundary conditions in A. N. Panchenkov's article in this collection. End footnote]

Thus, there is complete correspondence between the movement of a hydrofoil at $Fr_{*}\to 0$ and that of a wing above a fluid surface at $Fr_{*}\to\infty$ The solution to equation

$$\Gamma(\bar{y})=\frac{a_{\bar{h}}}{2\lambda(\bar{y})}\left\{\alpha(\bar{y})-\frac{1}{2\pi}\int_{-1}^{+1}\Gamma'(\bar{\eta})\left[\frac{1}{\bar{y}-\bar{\eta}}+G(\bar{y}-\bar{\eta})\right]d\bar{\eta}\right\} \qquad (2)$$

for $Fr_{*}\to 0$ determines the value of circulation over the span of a wing moving at a high speed above a fluid surface.

The procedure for solving equation (2) worked out in [1] gives the calculated formulae for finding the circulation at several nodal points on the span

$$\left.\begin{aligned}
&\Gamma^1=\Gamma^7=\frac{f^1}{a_1}+\\
&\quad+\frac{k_5(1{,}9142k_4-0{,}1464k_2)+k_6(0{,}1464k_1-1{,}9142k_3)}{a_1(k_1k_4-k_2k_3)}\\
&\Gamma^2=\Gamma^6=\frac{k_5k_4-k_6k_3}{k_1k_4-k_2k_3}\\
&\Gamma^3=\Gamma^5=\frac{f^3}{a_3}+\\
&\quad+\frac{k_5(0{,}9142k_4-0{,}8536k_2)+k_6(0{,}8536k_1-0{,}9142k_3)}{a_3(k_1k_4-k_2k_3)}\\
&\Gamma^4=\frac{k_1k_6-k_5k_2}{k_1k_4-k_2k_3}
\end{aligned}\right\}, \quad (3)$$

where

$$k_1=a_2-\frac{1{,}9831}{a_1}-\frac{1{,}0921}{a_3};$$

$$k_2=-\frac{0{,}2144}{a_1}-\frac{1{,}4421}{a_3}; \qquad a_1=\frac{2\lambda_1}{a_0}+\frac{2}{\sin\tau_1};$$

$$k_3=-\frac{0{,}1517}{a_1}-\frac{1{,}0196}{a_3}; \qquad a_2=\frac{2\lambda_2}{a_0}+\frac{2}{\sin\tau_2};$$

$$k_4=a_4-\frac{0{,}0164}{a_1}-\frac{1{,}3465}{a_3}; \qquad a_3=\frac{2\lambda_3}{a_0}+\frac{2}{\sin\tau_3};$$

$$k_5=f^2+\frac{1{,}036f^1}{a_1}+\frac{1{,}1945f^3}{a^3}; \qquad a_4=\frac{2\lambda_4}{a_0}+\frac{2}{\sin\tau_4}.$$

$$k_6=f^4+\frac{0{,}112f^1}{a_1}+\frac{1{,}5774f^3}{a^3};$$

Here $f(\bar{y})$ describes the change in the angle of zero-lift under the free surface:

$$f_1=-\frac{G_{20}\left(\frac{\omega}{\tau}\right)A_0^1}{4};$$

$$f_2 = -\frac{G_{41}\left(\frac{\omega}{\tau}\right)A_0^1}{2} + \frac{3G_{40}\left(\frac{\omega}{\tau}\right)A_1^1}{4} + \cos^2\tau\,\frac{3G_{40}\left(\frac{\omega}{\tau}\right)A_0^1}{4};$$

$$f_3 = -\frac{3G_{62}\left(\frac{\omega}{\tau}\right)A_0^1}{4} + \frac{3G_{61}\left(\frac{\omega}{\tau}\right)}{4}(A_0^1 + A_0^3) -$$

$$-\frac{5G_{60}\left(\frac{\omega}{\tau}\right)}{64}(2A_0^1 + 3A_0^3 + A_0^5) - \frac{G_{41}\left(\frac{\omega}{\tau}\right)A_1^1}{2} +$$

$$+\frac{3G_{40}\left(\frac{\omega}{\tau}\right)}{16}(A_1^1 + A_1^3) - \frac{G_{20}\left(\frac{\omega}{\tau}\right)A_0^1}{4} +$$

$$+\cos^2\tau\left[3G_{61}A_0^1 - \frac{30G_{60}\left(\frac{\omega}{\tau}\right)}{16}(A_0^1 + A_0^3) + \frac{3G_{40}\left(\frac{\omega}{\tau}\right)A_1^1}{4}\right] -$$

$$-\cos^4\tau\,\frac{5G_{60}\left(\frac{\omega}{\tau}\right)A_0^1}{4}. \qquad (4)$$

(At $f(\overline{y})$ the subscript designates the order of approximation and the superscript - the cross section number.) These formulae consider the planform of the wing and the state of motion.

At $Fr_{в}\to 0$ $\varphi_{mn}=-1.$ Function $\xi\frac{\overline{h}}{\lambda}$, which considers the effect of the interface on the angular coefficient of dependence $C_{y_{\overline{h}}}=f(\alpha)$--- and is part of the formula for finding C_y and C_x, has a large value.

If we know the circulation distribution, we can find the function with the formula

$$\xi_1=\xi\left(\frac{\overline{h}}{\lambda}\right)(1+\tau_1)=\frac{2\alpha_{\text{геом}}}{A_0+A_1\tau^2+A_2\tau^4+A_3\tau^6+m}-\frac{\pi\lambda}{\alpha_0}, \tag{5}$$

where

$$A_m=\Gamma^4_m+2\sum_{n=1}^{3}\Gamma^n_m\sin\theta_n,$$

τ_1 is the Glauert correction.

This formula was used to calculate corrections ξ_1 for several series of wings with different geometric parameters.

Rectangular wing (Fig. 1). A series of wings with the following aspect ratios was selected for the calculation

$$\lambda_0 = \frac{a_0}{2}; \quad \frac{3}{4}a_0; \quad a_0; \quad \frac{5}{4}a_0; \quad \frac{3}{2}a_0; \quad \frac{7}{4}a_0; \quad a_0=5{,}45.$$

In this case, $\lambda_0=\lambda_k=\lambda$.

Tapered wing (Fig. 2). Given a constant aspect ratio of λ_0 = 5.45, we will change the planform of the wing by changing the angle of taper; more precisely, by the value

$$q=1-\frac{C_e}{C_0'};$$
$$q=0{,}9;\ 0{,}75;\ 0{,}5;\ 0{,}25;\ -0{,}25;\ -0{,}5.$$

In this case,

$$\lambda_k=\frac{\lambda_0}{1-q\cos\theta_k}; \quad \lambda=\frac{2\lambda_0}{2-q}. \tag{6}$$

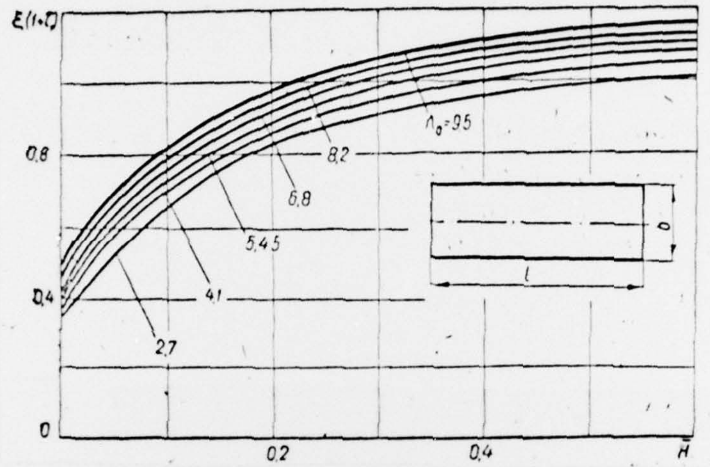


Fig. 1. Correction $\xi(1+\tau_1)$ for a rectangular wing:

$\lambda_0 = 5{,}45; \quad \frac{\omega}{\tau} = 0.$

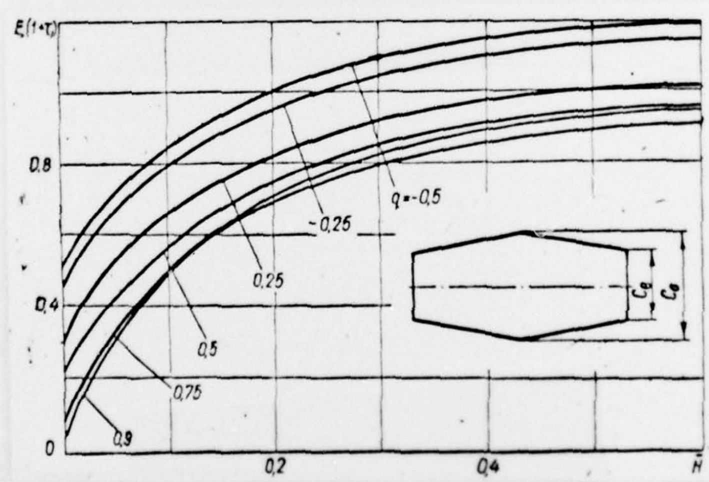


Fig. 2. Correction $\xi(1+\tau_1)$ for a tapered wing:

$\lambda_0 = 5{,}45; \quad \frac{\omega}{\tau} = 0.$

Double-tapered wing (Fig. 3). Its form can be changed by the size of the rectangular portion of the wing, as well as by the angle of taper. As in the previous case, λ_0 = 5.45; q = 0.9; 0.75; 0.5; 0.25; -0.25; -0.5.

For a double-tapered wing

$$\lambda_k = \frac{\lambda_0}{1-(\cos\theta_k - \chi)\cdot\frac{q}{1-\chi}}; \quad \lambda = \frac{2\lambda_0}{2+q(\chi-1)}, \qquad (7)$$

where $\chi = \frac{b_1}{b}$, and we will assign different χ, determined by formula (7)

$$\chi = \frac{1}{3}; \quad \lambda_4 = \lambda_0; \quad \lambda_1; \quad \lambda_2; \quad \lambda_3;$$

$$\chi = \frac{1}{2}; \quad \lambda_4 = \lambda_3 = \lambda_0; \quad \lambda_2, \quad \lambda_1;$$

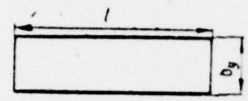
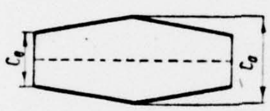
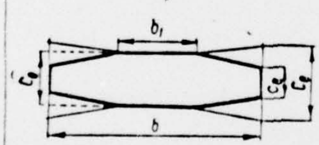
$$\chi = \frac{4}{5}; \quad \lambda_4 = \lambda_3 = \lambda_2 = \lambda_0; \quad \lambda.$$

Table 1.

№ крыла (1) \ H	0,00	0,05	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,55	0,60
1	0.33	0,515	0,651	0,75	0,822	0,876	0.917	0,949	0,973	0,992	1.01	1,02	1,03
2	0,364	0,556	0,693	0,791	0,863	0,916	0,956	0,987	1,01	1,03	1.04	1.06	1.07
3	0,997	0,592	0.729	0,826	0,897	0,949	0,989	1.02	1,04	1,06	1,08	1.09	1.10
4	0.427	0,625	0,761	0,858	0,928	0,98	1,02	1,05	1,07	1,02	1,10	1,14	1,19
5	0,456	0,654	0,79	0,886	0.955	1,01	1,04	1,07	1,10	1,12	1.13	1.14	-1,15
6	0,482	0,68	0,816	0,911	0,98	0,03	1,07	1,10	1,12	1,14	1,16	1,17	1,18
7	0,464	0,656	0.791	0,887	0,957	1.01	1,05	1,08	1,10	1,12	1.13	1,15	1,16
8	0.517	0,709	0,843	0,937	1,00	1,06	1,10	1,12	1,15	1.17	1,18	1,19	1,20
9	0,314	0,514	0,654	0,754	0,827	0,881	0,922	0,953	0,977	0,997	1,01	1,02	1,03
10	0,212	0,422	0,569	0,675	0,751	0,808	0,850	0,883	0,908	0,928	0,944	0,966	0,967
11	0,093	0,329	0,494	0,612	0,69	0,757	0,803	0,838	0,865	0,886	0,902	0,916	0,927
12	0,028	0,301	0,491	0 623	0,787	0,785	0,835	0 873	0,901	0,928	0,941	0,955	0,969
13	0,488	0,671	0,806	0,902	0,970	1,02	1,06	1,09	1,11	1.13	1,15	1,16	1,17
14	0,557	0,743	0,877	0,971	1.04	1,09	1,13	1,16	1,18	1,20	1,21	1,23	1,24
15	0,308	0,508	0,649	0,749	0,821	0,875	0,916	0,948	0,972	0,991	1.00	1,02	1,03
16	0,217	0,425	0,572	0,677	0,753	0,809	0,851	0,884	0,909	0,929	0,945	0,957	0,968
17	0,135	0,361	0,521	0,635	0,717	0,777	0,822	0,857	0,888	0,904	0,920	0,933	0,944
18	0,105	0,353	0,528	0,651	0,74	0,804	0,852	0,888	0,916	0,937	0,954	0,968	0,979
19	0,473	0,666	0,801	0,896	0,966	1,02	1,06	1,09	1,11	1,19	1,14	1,16	1,17
20	0,545	0,737	0,870	0,965	1,03	1,08	1,12	1,15	1,17	1,19	1,21	1,22	1,23
21	0,319	0,518	0,658	0,758	0,831	0,884	0,925	0,956	0,981	1,00	1,01	1,03	1,04
22	0,244	0,460	0,595	0,699	0,774	0,83	0,872	0,904	0,998	0,948	0,964	0,977	0,987
23	0,184	0,403	0,557	0,667	0,747	0,806	0,85	0,883	0,909	0,93	0,945	0,959	0,97
24	0,169	0,4	0,504	0,681	0,765	0,827	0,873	0,907	0,934	0,955	0,972	0,985	0,996
25	0,450	0,644	0,78	0,876	0,946	0,998	1,04	1,07	1,09	1,11	1,13	1,14	1,15
26	0,504	0,696	0,831	0,927	0,997	1,05	1,09	1,12	1,14	1,16	1,18	1,19	1,20
27	0,346	0,543	0,682	0,780	0,851	0,904	0,944	0,975	0,999	1,02	1,03	1,05	1,06
28	0,3	0,5	0,64	0,74	0,812	0,866	0,906	0,937	0,961	0,981	0,996	1,01	1,02
29	0,263	0,466	0,609	0,710	0,784	0,839	0,88	0,911	0,936	0,955	0,971	0,983	0,994
30	0,248	0,454	0,599	0,702	0,777	0,832	0,874	0,906	0,930	0,950	0,966	0,978	0,989

KEY: (1) Wing No.

Table 2.

(1) Наименование крыла	(5) Форма крыла в плане	$\lambda(\bar{y}) = \frac{l}{B(y)}$	$q = 1 - \frac{C_e}{C_0}$	$\chi = \frac{B_1}{B}$	(6) № крыла
(2) Прямоугольное		2,725	0	1	1
		4,0845			2
		5,45			3
		6,8125			4
		8,175			5
		9,5705			6
(3) Трапецоидальное		5,45	−0,25	0	7
			−0,5		8
			0,25		9
			0,5		10
			0,75		11
			0,9		12
(4) Двоякотрапецоидальное		5,45	−0,25		13
			−0,5		14
			0,25	$\frac{1}{3}$	15
			0,5		16
			0,75		17
			0,9		18
			−0,25		19
			−0,5	$\frac{1}{2}$	20
			0,25		21
			0,5		22
			0,95		23
			0,9		24
			−0,25	$\frac{4}{5}$	25
			0,5		26
			0,25		27
			0,5		28
			0,75		29
			0,9		30

KEY: (1) Type of wing. (2) Rectangular. (3) Tapered. (4) Double-tapered. (5) Planform of wing. (6) Wing No.

Tables 1 and 2 show the results of the calculations for the selected series. The above calculations make it possible to come to certain conclusions about the selection of the planform of a wing working near a screen.

The curves in Figures 1-3 should be corrected at small depths. The small parameter method does not give us the correct solution at $\bar{H}\to 0.$

It is necessary to find further approximations which require very cumbersome calculations in order to obtain more accurate results. In the limiting case, $\bar{H}=0,$ functions $\xi_1=0,$ and

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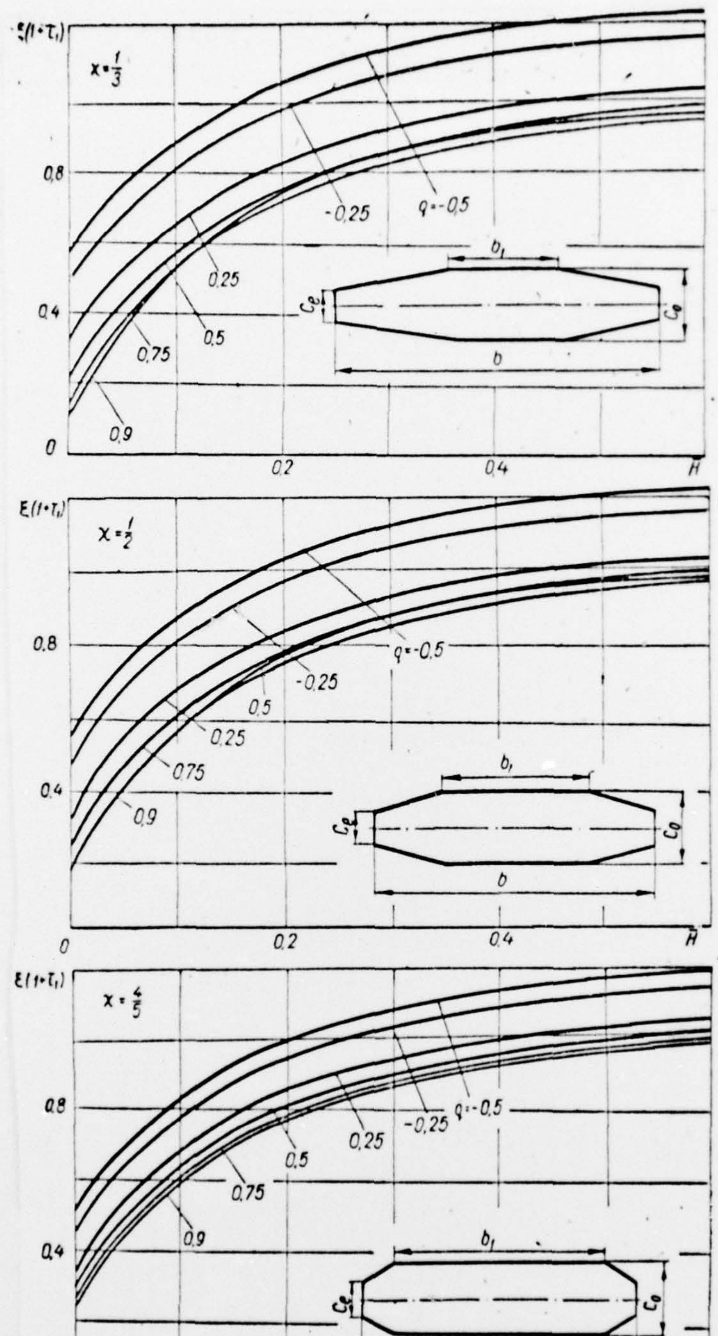

Fig. 3. Correction $\xi(1+\tau_1)$ for a double-tapered wing:

$\lambda_0 = 5{,}45;\ \frac{\omega}{\tau} = 0.$

induced drag disappears. Even a superficial analysis of the curves shows that the change of the wing planform has a considerable effect on its hydromechanical properties when moving near a screen. Neither the free surface, nor the unbounded fluid are as sensitive to the change in the wing planform as the screen. For example, the taper value of function ξ_1 can vary from 1.5-2 times, depending on the angle. This value changes very markedly for wings with large induced drag in an unbounded fluid, depending on the distance from the screen. Therefore, the selection of the planform of a wing near a screen requires very careful study. The value of ξ_1, and its first derivative, which expresses the slope of the curve, are necessary for designing airfoil systems moving near a screen and for calculating their stability.

Biblicgraphy

1. Ковальчук С. В., Ткаченко И. П. — В кн.: Гидротехника и гидромеханика, «Наукова думка», К., 1963.
2. Панченков А. Н. Гидродинамика подводного крыла. «Наукова думка», К., 1964.
3. Multhopp H. — Luftfahrtforschung, 1938, 15, 4.

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C557 USAIIC	1	ETID	3
C591 FSTC	5	NIA/PHS	1
C619 MIA REDSTONE	1	NICD	5
D008 NISC	1		
H300 USAICE (USAREUR)	1		
P005 ERDA	2		
P055 CIA/CRS/ADD/SD	1		
NAVORDSTA (50L)	1		
NAVWPNSCEN (Code 121)	1		
NASA/KSI	1		
544 IES/RDPO	1		
AFIT/LD	1		